METHOD AND APPARATUS FOR BACKGROUND
ADJUSTMENT IN COLOR REPRODUCTION DEVICES

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BACKGROUND

1.   Field

This disclosure relates to color copiers, more particularly to a method for adjusting

10   background colors in color copiers.

2.   Background

Color reproduction devices, such as copiers and fax machines, typically have a

processing pipeline that converts a scanned image into data, and then processes the data into

the appropriate format for printing. For example, a user places a color original on the platen

15   of a color copier or into the tray of a fax machine. The device scans the document using a set

of red, green and blue (RGB) sensors and produces a data representation in terms of the RGB

signals at each location on a pixel grid. In many applications, the RGB data is then converted

to a luminance/chrominance color space because this space makes it possible to separately

process chromatic and intensity information. Additionally, it is possible to represent the

20   chromatic and intensity information at different resolutions, thus the image in the luminance-

chrominance color space can be represented more compactly than in an RGB color space.

Luminance-chrominance color spaces typically have three components. One example

of this type of color space is CIE Lab. "L" represents the dark-to-light lightness dimension.

"a" and "b" represent the chrominance components. Although CIE LAB is also designed so

25   that equal distances between points in the space are approximately equal in terms of perceived

color difference, this feature is not central to the problem with which we are concerned.

Other luminance-chrominance color spaces can be used where this property is not present.

Technically, CIE L values are lightness and the exact definition is different than the definition

of luminance. Either definition could be used to code the intensity information at a pixel.

30   The intensity dimension will be referred to here as lightness or L values.

In some cases, such as if the paper upon which the original image resides were not

white, the background pixels of the LAB image would be printed as colors. This takes a

longer amount of time and wastes toner or ink to render the background color, which was

more than likely not desired. Most users that are copying from a colored piece of paper do

not want the color reproduced. Typically, if users want a copy that is on colored paper, the user will load color paper into the copier before copying the original.

Currently, most copiers employ background suppression to eliminate the background paper color. Most perform this suppression in the lightness component only. The lightness of the background pixels are typically mapped to white, setting their lightness values to the corresponding white level for that copier. In most copiers, lightness will be set to white at 255, assuming 8-bit processing where values range from 0 to 255.

Once the LAB space is adjusted to suppress the background, the LAB data is mapped to the appropriate color space for that print engine. These are typically a cyan-magenta-yellow (CMY) space or a cyan-magenta-yellow-black (CMYK) space.

However, a problem occurs if a portion of the original has highlighting, where a lighter color is used to set off a darker object. Other examples exist, but the most common type is where text is highlighted with a light yellow, pink or blue highlight surrounding the text characters. Highlight colors are also frequently used in maps. With the usual method of color processing, the lightness of these pixels surrounding the text characters is mapped to white and the highlighting is not preserved in the color copy, which may have been desired.

Therefore, it would be useful to have a method of background suppression that allows preservation of these highlighted colors, while avoiding the unnecessary extra processing and toner/ink use that would occur with colored paper.

SUMMARY

An aspect of the disclosure is a method for background adjustment. A background lightness level in an original image is estimated. Pixels are then converted to a luminance-chrominance color space, such as LAB. Many luminance-chrominance spaces are well known in the prior art and would also be applicable. Pixels having lightness levels equal to the background lightness level are mapped to a value corresponding to white as background pixels. Chroma values for the background pixels are compared to a threshold and adjusted as needed, either by adjusting the lightness value or by removing the chrominance values. The LAB data is then converted to output space. Also disclosed is a color reproduction device having a chroma adjustment module.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention may be best understood by reading the disclosure with reference to the drawings, wherein:

Figure 1 shows a block diagram of one embodiment of a color reproduction device, in accordance with the invention.

Figure 2 shows a block diagram of one embodiment of a method for background adjustment, in accordance with the invention.

Figure 3 shows a flowchart of one embodiment of a method for determining a background lightness level, in accordance with the invention.

Figure 4 shows a graph of lightness mapping in a background suppression process.

Figure 5 shows a graph of a histogram showing a high peak value for determining a background lightness level.

Figure 6 shows a graph of the top lightness plane of a color table.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Figure 1 shows a typical pipeline architecture for a color copier. The original document is scanned on a scanner 12 to form red-green-blue (RGB) values. The RGB is converted to a luminance-chrominance color space such as LAB at 14, where L represent the luminance/lightness component and a and b are the chrominance components, sometimes referred to as C1 and C2. This particular color space will be referred to here as LAB rather than 'Lab', to prevent confusion. The chrominance components 'a' and 'b' will be referred to as such when referred to individually. Since most documents are not perfectly white and vary from one paper type to another, background suppression is employed at 16 to map paper background to white. If this process was not performed, the printer could render the light background color, using unnecessary resources and providing an undesirable result.

Background suppression is typically done using only the lightness component for low cost copiers, where the lightness of paper substrate is mapped to white. In a typically 8-bit printing application, this value is set at L=255. In current color reproduction devices, the background-suppressed data is then converted to output device space at 20, for printers this is typically either cyan-magenta-yellow-black (CMYK), or cyan-magenta-yellow (CMY). Output device space as used here is the color space used by the output device, and it will also be referred to as output space. Finally, the print engine in the reproduction device then prints

the output space data at 22. Current systems do not include the chroma adjustment module 18 shown in Figure 1, which will be discussed in more detail below.

Figure 2 shows one embodiment of a method to adjust chroma values to preserve highlight colors while suppressing background colors in accordance with the invention. Once the background level is determined, as will be discussed with regard to Figures 3, 4 and 5, it is mapped to white in the background suppression module.

The lightness mapping function maps the background lightness to the value corresponding to white, in the 8-bit example discussed previously, this is the value 255. However, it also maps the lightness of some highlight colors to white as well. This causes the difficulty in preserving these highlight colors. Additionally, many original document substrates are slightly colored, such that they have non-zero chrominance values a and b. These colored backgrounds can be reproduced causing a colored background in the reproduction. Typically, this appears as colored dots printed in background regions of the reproduction. These color dots can slow down the printing speed since they can prevent the printer from skipping white space, as well as unnecessarily consuming toner or ink.

The chrominance adjustment module 18 of Figure 1 offers a solution to this problem. Once the background is mapped at 26 of Figure 2, the value of lightness is checked to see if it is substantially equal to the value corresponding to white (L=White) at 28. The degree to which the value of lightness equals the lightness value corresponding to white is left to the system designer. As used here, a value substantially equal to the value corresponding to white may vary by up to two percent (2%). If the answer is 'No' then the pixel value is converted to output space at 26. If the lightness is equal to the value corresponding to white, the chroma value is compared to at least one threshold at 30.

In one embodiment, the chroma value C is substantially equal to $\sqrt{a^2 + b^2}$. Other formulations of chroma can be used as well, such as C = |a| + |b|, or C = max(|a|, |b|). At each pixel, if the chroma is greater than a first threshold, then the color of that pixel is preserved. The lightness of that pixel is set to a lower value L at 32. If the chroma is less than or equal to a second threshold, the chroma is removed by setting a=0 and b=0. As an example, the two thresholds could both be set to 10, and lightness adjusted to 254. In another, both of the thresholds could be set to 20 for text mode, where the system is processing mostly text, and 10 for all other modes. All of the above specifics are merely for discussion purposes; no limitation on the scope of the invention is intended.

The two thresholds, the first for determining whether to preserve the chroma value, and the second for determining whether to remove the chroma may be equal or different. If these two thresholds are equal, effectively only one threshold is used. This choice is left to the system designer.

As can be seen by this process, the mapping of the lightness values and the determination of the background level at 26 must be done very carefully. In removing the background, the first step is estimating the background lightness level. Figure 3 illustrates one possible expansion of the process to estimate background level 26, using lead-edge data. The lead-edge is usually the first half-inch of the page, where most documents have a top margin. In order to have an efficient hardware implementation, background estimation is processed line by line. The line of data is converted to LAB space at 24, the same process as in 24 of Figure 2.

The input RGB data is first converted to LAB typically using a 3x3 matrix or 3-D look-up-table (LUT). The lightness is mapped according to a function:

$$L_{out} = L_{in} * 255 / L_w \quad L_{in} \le L_w$$
$$L_{out} = 255 \quad L_{in} > L_w$$

Where L_w = white-offset. In one embodiment, the offset was chosen between 5-20 depending on the spread of the background histogram. An example of this lightness mapping function is shown in Figure 4.

For each line, a histogram is constructed to estimate the background level at 42. The background level is defined to be the high peak value at 44, such as that shown in the histogram in Figure 5.

Some documents, such as printed photographs, may not have a margin on the lead-edge. In this case, the detected white will be the peak of the image histogram rather than the background. If this estimated white is used for background removal, most of the highlight content would be removed as well. To prevent this from happening, a minimum white is used so that if the detected, or current, white is below the minimum white, it is not used in estimating document background level. This is shown in 46 in Figure 3. If the current white is above the minimum white at 48 a further check is performed to determine if the current white is above the previous background level. This determines which adaptation constant is used. The new background is given by:

New white = old white * (1-k) + k * current white.

In one embodiment, for example, the k value is set to 0.25 when the current white is lower than the old white, and the value of 0.125 is used when the current white is higher than the old white. Selection of the numbers used is left to the system designers and are only intended as an example. This then updates the background as shown at 49.

For the first line, there is no previous white estimate, so an initial white value is used. The initial white is set so that most common originals are reproduced reasonably. The initial white is the default white when the lead-edge of the original is too dark as in the case of printed photograph. As an example, the initial white may be set to 230 and the minimum white may be set to 220.

This background mapping function is then used prior to the chroma adjustment process, as shown in Figure 1. The chroma adjustment module shifts the LAB values as necessary to preserve highlight colors, as discussed above. The printer conversion module will convert the adjusted LAB data to CMYK, CMY, RGB or other desired output space.

For example, in a LAB-to-CMYK module, each pixel is mapped to CMYK values via a three dimensional LUT. For background and some highlight colors, the top L plane (L = 255) defines the color reproduction. Figure 6 shows the central portion of color table values of the top L plane. For example, assume that a 17x17x17 table is used. This results in a grid point spacing to be 16. The color table is designed so that the background (L=255, a=0, and b=0) is mapped to C=0, M=0, Y=0, and K=0. As shown in Figure 6, any input pixel with L of 255 and a and b values within the circle will be mapped to the center (L=255, a=0, and b=0). This ensures that the background is reproduced cleanly, without printing any CMYK dots.

An alternative approach would be to only process those pixels with lightness values less than 255 (L<255). For pixels for which L=255, the output would automatically be set to the appropriate values in the particular output space. For example, in the LAB-to-CMYK module example above, pixels for which L=255 would automatically have their output values set to C=0, M=0, Y=0 and K=0, bypassing the lookup table.

Some highlight colors may have chroma values above threshold, outside the circle of Figure 6. Assuming the formulation $C = \sqrt{a^2 + b^2}$, the chrominance (a and b) was preserved by the chrominance adjust module, but its L value was compressed by the lightness mapping to L'. In order to reproduce the highlight color, the color plane corresponding to L' (the top L

plane) is adjusted so that any color that has not been removed is preserved. This is achieved by setting the color table entries near the neutral axis to much higher values than would be required according to a colorimetric reproduction scheme. This ensures that any color not removed by the chrominance adjustment module is reproduced with adequate density to be easily visible. In this manner, the printer resources are not wasted reproducing the background colors. At the same time, highlight colors are preserved.

Thus, although there has been described to this point a particular embodiment for a method and apparatus for background removal in color reproduction requirements, it is not intended that such specific references be considered as limitations upon the scope of this invention except in-so-far as set forth in the following claims.